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Fertilizing Field Crops in Ohio

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FERTILIZERS are natural or manufactured chemical salts, organic by-products, and wastes used singly or in mixtures to supply nitrogen, phosphoric acid, and potash in forms readily available to crops. They are used to supplement the natural supply of these elements in soils that fail to yield up sufficient amounts in available form for best growth. Only in rare cases do Ohio soils fail to supply enough of all other mineral elements needed by crops.

AVAILABILITY IN FERTILIZERS

In general, nutrients must enter the soil solution to be usable by plants. However, some crops can obtain mineral elements from relatively insoluble materials. Fertilizers vary in the rate and extent to which their nutrient elements become available. Potash salts commonly used in fertilizers are all water soluble and hence readily available. Most of the phosphoric acid contained in superphosphate, bone meal, and basic slag is readily used by all crops, while that contained in raw rock phosphate is slowly available except to sweet clover and a few other crops. Inorganic nitrogen fertilizers such as sulfate of ammonia are water soluble and quickly available. Nitrogen in organic materials must undergo oxidation to ammonia and nitrates through the activity of soil microorganisms before it can be used. This action is very rapid in the case of urea, fairly rapid with animal tankage or cottonseed meal, and very slow in the case of garbage tankage, peat, or leather scraps.

THE OHIO FERTILIZER LAW

For the protection of the consumer, manufacturers of fertilizers are required by law to attach to each package of fertilizer sold a label or tag stating the weight and analysis of the contents. The analysis gives the guaranteed minimum percentages of total nitrogen, available phosphoric acid, and water soluble potash. The availability of the phosphoric acid in bone meal, tankage, basic slag, and raw rock phosphate is not readily determined by chemical means, hence, only total phosphoric acid need be guaranteed with these materials when sold unmixed. The presence of low grade organics such as peat, leather, hair, etc., must be stated. Sale of mixed fertilizers in which the sum of the percentages of nitrogen, available phosphoric acid, and potash is not sixteen or more is forbidden.

In stating the analysis of a mixed fertilizer, such as a 2-12-6, the first figure refers to the percentage of nitrogen, the second to the percentage of available phosphoric acid, and the third to the percentage of water soluble potash. The Ohio law requires no guarantee of availability in the case of

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nitrogen, there being no generally accepted chemical method of determining it. The customer's best protection against low grade nitrogen is to purchase only high analysis mixtures—containing 20 per cent or more of total plant food—since the opportunity for incorporating objectionable amounts of low grade materials in such mixtures is limited.

The Director of Agriculture is charged with the administration of the fertilizer law and is empowered to collect and analyze samples and to publish the results. By reference to these published reports, available free upon request from the State Department of Agriculture, Columbus, Ohio, the farmer can ascertain what companies have failed to meet their guarantees.

Carriers of Nitrogen, Phosphoric Acid, and Potash

The following table summarizes briefly the properties of the more important fertilizer materials:

Table I. Properties of Common Fertilizer Ingredients

Material	Composition, Per Cent			Degree of availability	Source	Remarks
	Nitrogen	Available Phos. acid	Potash			
Nitrate of soda....	15.5-16	.....	.....	High	Chile and synthetic	
Sul. of ammonia...	20–21	.....	.....	High	By-product of coke ovens and synthetic	Leaves acid residue; rected by equal weight limestone.
Cyanamid	22	.....	.....	High	Synthetic	About equal to lime in neutralizing power.
Urea	46	.....	.....	High	Synthetic	
Animal tankage..	4–8	3–8	.....	Medium	Packing houses	Used as conditioner.
Tobacco stems....	1.5–3.5	trace	5–10	Medium	Tobacco waste	Used as conditioner.
Garbage tankage..	2.5–3.5	trace	trace	Very low	Garbage reduction plants	Used as conditioner, ability may be incr by acid treatment.
Superphosphate...	.....	16–46	.....	High	Rock phosphate treated with sulfuric acid	Most common source o acid in mixed fertilize
Steamed bone meal.	1.5	23–26 (total)	.....	High	Packing house	Little used in mixed lizers.
Basic slag.....	.....	10–18	.....	High	Smelting of phosphatic iron ores	Lime equivalent to 8 cent carbonate of lim
Raw rock phos.....	.....	25–30 (total)	.....	Low	Mined in Tennessee, Florida and elsewhere	Not used in mixed lizers.
Muriate of potash: Foreign	.....	.....	50	High	Germany and France	Principal source in fertilizers.
Domestic	.....	.....	60	High	Principally California	
Sulfate of potash.	.....	.....	48	High	Germany and France	Used in tobacco fertil
Kainit	.....	.....	12–16	High	Germany and France	
Manure salts. ...	.....	.....	20–40	High	Germany and France	
Ammo-Phos	16	20	.....	High	Nitrogen synthetic	Affects soil reaction larly to ammonium sul
	11	48	.....	High		
Nitrophoska	15	30	15	High	Nitrogen synthetic	

Conditioner and Filler

Certain fertilizer chemicals, such as superphosphate and sulfate of ammonia, when mixed tend to cake; some, such as nitrate of soda, take up moisture from the air and become damp and lumpy. To keep mixtures containing such materials drillable, manufacturers add 200 to 400 pounds per ton of drier or conditioner, such as tankage, tobacco stems, cyanamid, pulverized dolomitic limestone, ground phosphate rock, dry muck, or peat.

The less costly of these materials also are often added to increase the weight of the mixture, and are then called fillers. For example, the nutrients in 1 ton of 1-11-4 can be supplied in 100 pounds sulfate of ammonia, 1100 pounds 20% superphosphate, and 160 pounds muriate of potash. These total 1360 pounds, permitting the use of 640 pounds of "filler." As a rule

the lower analysis mixtures contain the most filler. Any fertilizer nutrients in the filler or drier may be claimed in the analysis. This is questionable practice in the case of the nitrogen in organics like garbage tankage and muck.

In home-mixed fertilizer, drier may be omitted if the ingredients are dry and the fertilizer is to be drilled soon after mixing. Claims of superiority for commercial mixtures because they contain certain fillers or driers are unwarranted aside from that of superior drilling quality. Excepting lawn fertilizers, where some organic nitrogen may be desirable, the substitution of organic carriers for sulfate of ammonia or other mineral forms of nitrogen commonly does not increase and is likely to reduce the efficiency of a mixed fertilizer under Ohio conditions, provided the fertilizer drills satisfactorily in either case.

Standard Ratio Fertilizers

Competition for sales has led manufacturers to market many more mixed fertilizer analyses than can be justified by soil and crop requirements. Unnecessary multiplicity of analyses makes manufacturing and storage costs higher, and the tendency is for these costs to be passed on to the consumer. To discourage this tendency, and the manufacturing of low-analysis, high-filler mixtures, soil specialists of Ohio and four other mid-western states, in cooperation with the fertilizer manufacturers, adopted in 1928 a list of fifteen mixed fertilizer ratios which were believed to satisfy all legitimate requirements in area represented.

Recommendations of the agricultural experiment stations and colleges have been confined to fertilizers having these ratios and containing a total of not less than 20 per cent of plant food. Superphosphate and other unmixed materials also have been recommended. This policy has led to marked improvement in the quality of fertilizers sold in Ohio, and has reduced the cost per pound of plant food to the consumer.

The ratios and minimum analyses now recommended in Ohio are shown in Table 2. This list includes two ratios not in the original fifteen. Higher strength mixtures that are whole number multiples of the standard ratios are also recommended. Examples are shown in the table.

Table 2. Standard ratios and approved analyses recommended in Ohio

Ratio (Nitrogen; phosphoric acid; potash)	Minimum analysis (Not less than 20%)	Higher analyses	
1-6-3	2-12- 6	3-18- 9	4-24-12
1-7-2	2-14- 4	3-21- 6	4-28- 8
1-3-1	4-12- 4	8-24- 8	9-27- 9
2-5-3	4-10- 6	8-20-12	
1-2-2	4- 8- 8	8-16-16	9-18-18
3-4-3	6- 8- 6		
1-4-5	2- 8-10		
1-3-6	3- 9-18		
5-3-2	10- 6- 4		
0-7-3	0-14- 6	0-21- 9	0-28-12
0-1-1	0-12-12	0-20-20	0-24-24
0-3-7	0- 6-14	0- 9-21	0-12-28

TABLE 3. RECOMMENDED USE OF THE STANDARD RA

I.—MODIFYING CONDITIONS:

Column "manured or clovered" assumes that:

1. Eight tons or more per acre of well preserved farm manure was used on the immediate crop or in preceding year;

or 2. A full crop of clover, or other legume, green or mature, was plowed under for the immediate crop;

or 3. Both.

II.—RATE

Figures directly beneath the analy... are rates in pounds per acre. For ... double- or triple-strength fertilizer ... the rate will be one-half or one-th... that stipulated below, respectively.

Light Colored Soils				How Apply Fertilizer	CROP
Sandy Soils		Silt Loams, Clay Loams, and Clays			
Manured or Clovered	*Neither*	*Manured or Clovered*	*Neither*		
0–14–6 125–175 150–200	2–12–6 150–200 175–225	0–14–6 125–175 150–200	2–12–6 125–175 150–200	In hill On drilled corn	CORN
6–8–6 500–1000	6–8–6 1000–1500	6–8–6 500–1000	6–8–6 1000–1500	In row	EARLY POTATOES
4–8–8 (2–8–10) 500–1000	4–8–8 1000–1500	4–8–8 (2–12–6) 500–1000	4–8–8 1000–1500	In row	LATE POTATOES
2–8–10 (2–12–6) 500–600 15 lbs. nitrogen	3–9–18 500–600 20 lbs. nitrogen	2–12–6 500–600 15 lbs. nitrogen	4–10–6 500–600 25 lbs. nitrogen	In row	TOBACCO
				In row	SUGAR BEETS
None	0–14–6 175–225	None	0–14–6 150–200	Broadcast	OATS, RYE OR BARLEY Not seeded to meadow
0–14–6 200–300	2–12–6 (0–14–6) 250–300	0–20–0 150–250	2–14–4 (0–14–6) 200–300	Broadcast	WHEAT not seeded to meadow, or ANY SMALL GRAIN seeded to 1-yr. mea...
0–14–6 300–350	2–12–6 (0–14–6) 300–400	0–20–0 250–300	2–14–4 (0–14–6) 300–400	Broadcast	SMALL GRAIN seeded to alfalfa or ... meadow to be cut 2 years or m...
None	0–14–6 125–175	None	0–14–6 100–150	Broadcast	SOYBEANS
0–20–0 200–300	0–12–12 250–350	0–20–0 200–300	0–14–6 250–350	Top dress	ALFALFA Established stand
None	10–6–4 200–400	None	10–6–4 200–400	Top dress	TIMOTHY Established stand
0–20–0 200–300	0–14–6 300–400	0–20–0 200–300	0–14–6 300–400	Top dress	PERMANENT PASTURE Entire area
None	20–40 lbs. nitrogen	None	20–40 lbs. nitrogen	Top dress	PERMANENT PASTURE On fenced area for early grazi...
4–12–4 400–500	6–8–6 500–600	4–12–4 400–500	6–8–6 500–600	Broadcast	LAWNS AND FAIRWAYS New seedings
10–6–4 in three applications, spring, early summer and fall, 100 to 150 lbs. each time, or 400–600 lbs. cottonseed meal, soybean meal or milorganite in May.				Top dress	LAWNS AND FAIRWAYS Established

III.—ANALYSIS

1. "Phosphate" means superphosphate (16 to 46%), basic slag or bone, the amount recommended being in terms of 20% superphosphate.
2. "Nitrogen" to be applied in any readily available form. Thus 20 pounds of nitrogen could be supplied by the use of 95 pounds of sulfate of ammonia, 125 pounds of nitrate of soda, or the necessary amounts of other nitrogen carriers.
3. The series of figures in the analyses expresses the percentages of total nitrogen, available phosphoric acid, and water soluble potash, respectively.

Dark Colored Soils				Notes
Silt Loams, Clay Loams, and Clays		Mucks and Peats		
Manured or Clovered	*Neither*	*Manured or Clovered*	*Neither*	
0–14–6	0–14–6	0–12–12	0–12–28 (0–12–12)	With improved fertilizer depositors use the higher rates shown. (See p. 6.)
100–150	100–150	100–150	100–150	Use analysis in parentheses if preferred analysis is not available.
125–175	125–175	125–175	125–175	
6–8–6	6–8–6	0–12–28	0–12–28	
1000–1000	1000–1500	500–1000	1000–1500	
4–8–8	4–8–8	0–12–28	0–12–28	Use analyses in parentheses when planting is May 15 or later.
(2–12–6)	1000–1500	500–1000	1000–1500	
500–1000				
2–12–6	2–8–10			Use analyses in parentheses if preferred analysis is not available.
300–400	(2–12–6)			Use heavier rates indicated for white burley.
	400–500			Apply nitrogen when plants have spread of 6 to 8 inches.
4–12–6	4–10–6			Nitrogen to be applied as a side-dressing at blocking time.
100–200	200–300			
	15 to 25 lbs. nitrogen			
None	None	None	None	
0–20–0	0–14–6	0–14–6	0–12–12	When wheat is the companion crop or alfalfa is seeded use heavier rates shown.
150–200	150–250	150–200	150–250	Use analyses in parentheses on the more productive light colored soils.
0–20–0	0–14–6	0–14–6	0–12–12	For wheat apply 15 to 25 lbs. nitrogen April 1 to 15 except under conditions specified on page 8.
200–250	250–350	200–250	250–350	
None	None	None	None	
0–20–0	0–14–6		0–12–12	Apply in early spring of third year and every second year thereafter. Preferably incorporated in soil with disk drill or spring tooth harrow.
150–200	200–300		150–250	
None	None	None	None	Apply March 15 to April 1 of third hay year and annually thereafter. Preferably incorporated in soil with disk drill.
0–20–0	0–14–6			Every third or fourth year. Preferably incorporated in soil with disk drill.
150–250	250–350			
None	15 to 30 lbs. nitrogen			Apply March 1 to April 1. Repeat about September 1 for fall pasture if needed. (Supplementary crops recommended for midsummer grazing.)
4–12–4	4–12–4			Supplementary treatment of 500–1000 lb. 0–20–0 incorporated in upper 3 to 4 inches of soil during preparation is recommended. 100 lbs. per acre equivalent to 2.3 lbs. per 1000 sq. ft.
400–500	500–600			
0–6–4 in three applications, spring, early summer and				If organics are used on thin stands of turf in the spring, an early fall application of 300–400 lbs. of 4–12–4 is desirable.
75 to 125 lbs. each time, or 300–500 lbs. cottonseed meal, soybean meal, or milorganite in May.				

Concentrated Fertilizers

By using certain highly concentrated materials such as treble superphosphate, ammonium phosphates, urea, muriate of potash, etc., manufacturers have been able to produce such concentrated mixtures as the 4-24-12, 4-28-8, 10-30-10, 0-28-12, and 0-24-24. These are commonly sold at a somewhat lower price per unit of plant food than the corresponding single strength mixtures. They offer the additional advantage of reducing the labor in hauling and applying.

Experiments have demonstrated that for Ohio conditions these concentrated fertilizers are fully equal to the lower strength mixtures when compared on an equal plant food basis. They are recommended with the single reservation that, before purchasing them, farmers determine whether their fertilizer equipment is adapted to applying the smaller acre rates required, and if not, consult their implement dealer regarding necessary changes.

Home Mixing of Fertilizers

Any of the standard analyses may be home-mixed with a saving of from $4 to $6 a ton in cash outlay. With reasonable care in mixing, such fertilizers will give results fully equal to factory made mixtures. Special precautions must be taken to incorporate "conditioner" in case the fertilizer is not to be drilled immediately. Directions for home-mixing can be obtained upon application to your county agent or to Agronomy Extension, The Ohio State University, Columbus, Ohio.

Methods of Application

That the location of the fertilizer with respect to the seed or plant may greatly influence its efficiency or safety has been demonstrated in numerous recent investigations. The following general principles relating to fertilizer placement have been fairly well established:

1. Greatest efficiency results from placing the fertilizer as close to the seed or plant as is possible without injuring the seed or seedling.
2. Injury results from too high a concentration of soluble salts in contact with the seed or seedling, nitrogen and potash salts being more likely to cause injury than phosphates. For a given amount of nutrients, high analysis fertilizers may carry less soluble salts than lower strength fertilizers.
3. Mixing of the fertilizer with too great a volume of soil may reduce the efficiency of phosphoric acid and potash salts, through their chemical reaction with certain soil constituents to form relatively insoluble compounds.
4. Soluble fertilizer salts move up and down with the soil water to some extent, but the movement laterally is much smaller.
5. Fertilizers placed either above or below the seed or in contact with it are apt to be damaging, while very little separation, from ½ to 1 inch, will prevent injury if the fertilizer is placed at the side of the seed.

Considerable recent improvement has been made in the design of fertilizer deposits, especially on corn and potato planters. The aim has been to obtain a lateral band type of placement. Most of the new corn planter depositors carry a V-shaped deflector which serves to split the fertilizer stream

into two bands, and a surrounding metal hood which prevents the two bands being pushed back together by the incoming soil. Potato planters carrying two disc openers for the fertilizer furrows have proven very satisfactory in obtaining the desired two-band placement.

For small grains, the ordinary grain drill fertilizer attachments have been found quite satisfactory, and fertilizer applied in the same operation as the seeding gives better results than if put on separately.

In applying fertilizers carrying phosphoric acid and potash to pastures or established stands of alfalfa, some incorporation with the soil is desirable. Ordinarily, this may be obtained by using a disc fertilizer drill and adjusting it to cut as deeply as possible. With alfalfa the fertilizer may be applied to the surface and incorporated with a spring tooth harrow. With side or top dressings of soluble nitrogen fertilizers, incorporation offers no advantage over mere surface application, since the first rain will carry these materials into the soil. Except on long time meadows or permanent pastures, applications of phosphate and potash fertilizers are best made at planting time.

Choice of Fertilizers

Several factors affect the proper choice of analysis and quantity. The nature of both soil and crop are important, also the amount and kinds of manure or crop residues plowed under, and certain climatic and economic factors. The need for potash is relatively high on muck and low on heavy clays. Nitrogen is less needed on dark than on light colored soils. Sandy soils are apt to be relatively deficient in all three elements. Practically all Ohio soils are responsive to phosphoric acid. Liming soils often increases the need for potash, and may decrease response to phosphoric acid if the soil reaction is raised to $pH\,7$ or above. Fertilizers generally show higher response on soils of low or medium fertility than on those of high natural fertility.

Animal manures contain relatively more nitrogen and potash than phosphoric acid, and require supplementing with high phosphate fertilizers. Leguminous crop residues decrease the need for nitrogen; they also reduce the need for the mineral elements, but to a lesser extent.

Crops differ in their response to the different elements. Wheat shows relatively high response to phosphoric acid, potatoes and corn to potash, and grasses to nitrogen. Some crops such as oats and soybeans show a low response to fertilizers in general, others like wheat and tobacco a high response. Heavier applications can be made profitably to high acre-value crops such as potatoes and vegetable crops than to low value crops like oats and hay. Crops making considerable growth in the early spring require more nitrogen than crops making most of their growth during warm weather. Similarly, an early planted crop needs more nitrogen than if the same crop is planted late. Quick growing crops such as lettuce and spinach require more fertilizer than slow growing crops like corn and hay. Legumes can fix air nitrogen and need minerals chiefly.

Nitrogen is most needed in cool seasons and in wet years with much leaching. Potash pays best in seasons that are abnormally cool or wet. Phosphates hasten maturity, particularly benefiting small grains in years of midsummer drouth, and corn in years of early frosts.

In periods when crop prices are low compared to fertilizers, less fertilizer can be used profitably than when the opposite relation exists.

Fertilizer Recommendations for Field Crops in Ohio

Fertilizer recommendations of the College of Agriculture and the Experiment Station for the common field crops under various soil conditions are presented in Table 3.* They are based on field experiments, the experience of farmers, and consideration of the facts mentioned in this bulletin. They will not meet all conditions accurately, and the farmer is urged to vary their use in accordance with his own experience and special soil conditions. Should more specific advice be desired, it is suggested that a sample of soil be sent to the College for free test and recommendation. Directions for taking and mailing soil samples and a statement of the supplementary information needed may be obtained from your county extension agent, or will be sent upon request addressed to Agronomy Extension, The Ohio State University, Columbus. Samples submitted will also be tested for lime needs.

"Hold-over" Effects of Fertilizers

The crop fertilized ordinarily can use only part of the nutrients applied. A considerable part of the phosphoric acid and potash and some of the nitrogen may "hold over" and be used by subsequent crops. In an experiment at Wooster, a broadcast application of 500 pounds of 4-16-4 to only one of the crops in a 4-year rotation has produced 70 per cent as much response the second year as in the first year, 50 per cent as much the third year, and 35 per cent as much the fourth year.

Hill or row applications may be more completely utilized and show less residual effect. Wheat, following liberally fertilized crops of potatoes, tobacco, or vegetables, needs little if any fertilizer. For a similar reason the hay crop to follow should be considered in fertilizing small grains. Averaging five years' results of experiments in nine Ohio counties, the direct effect of fertilizing wheat was an increase of 13.1 bushels, and the residual effect on the following clover an increase of 1200 pounds of hay. With low value crops like oats, the use of any fertilizer may depend on whether a hay crop is to be seeded.

Nitrogen Top and Side Dressings

The ready loss of nitrogen by leaching sometimes makes the use of liberal amounts at planting time unprofitable. Hence, delayed applications as top or side dressings of quickly available forms are advisable on certain crops. The economy of nitrogen side dressings on tobacco and sugar beets has been well demonstrated. Only rarely will corn pay for such a treatment. Early spring top dressings to wheat have shown, in several hundred tests over the state, an increase of about 1 bushel for each 3 pounds of nitrogen applied, equivalent to about 7 bushels for 100 pounds of sulfate of ammonia. Very thin stands and vigorously growing stands likely to lodge should not be topdressed.

Timothy meadows and bluegrass pastures may be profitably topdressed under the conditions specified in Table 3. This table also carries suggestions as to the rates and times of application for the other crops mentioned.

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*Similar tables of recommendations for vegetable and fruit crops are available upon request from Horticulture Extension, Ohio State University, Columbus, Ohio.